Global Climate-Change Impact Studies Centre,
Ministry of Climate Change & Environmental Coordination,
Government of Pakistan

Ministry of Climate Change

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RICARDO

– Mitigation pathways for black carbon emissions in Pakistan –

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Image Credit: https://m.toppersnotes.com/current-affairs/blog/the-need-to-curb-black-carbon-emissions-ul1Ga

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IAMC
Integrated Assessment Modeling Consortium
Founded 2007

Speaker: Kaleem Anwar Mir

01 Introduction

Statement of the problem

Key elements of the problem

- ✓ Incomplete Data on BC Emissions
- ✓ Lack of Scenario Analysis for Emissions Reduction
- ✓ Health and Climate Impacts – Approximately 114,000 annual deaths
- ✓ Need for Effective Policy Development

Research question

"What is the current state of black carbon (BC) emissions in Pakistan, and how will emissions evolve under different scenarios (Reference Emission Scenario (RES) and Accelerated Reduction Scenario (ARS)? What are the key sources of BC, and what mitigation strategies can significantly reduce BC emissions in Pakistan by 2050?"

IQAir

2018-2023

World's most polluted countries & regions annual average PM2.5 concentration (µg/m³)

Rank	Country/Region	2023	2022	2021	2020	2019	2018
1	Bangladesh	79.9	65.8	76.9	77.1	83.3	97.1
2	Pakistan	73.7	70.9	66.8	59	65.8	74.3
3	India	54.4	53.3	58.1	51.9	58.1	72.5

Specific objectives

- ✓ **Develop a BC Emissions Inventory for Pakistan (2021)**
- ✓ **Evaluate Baseline and Mitigation Scenarios (RES and ARS)**
- ✓ **Assess the Impact of Mitigation Strategies**
- ✓ **Provide Insights for Policymakers**

Necessity

- ✓ **Impact on Air Quality and Public Health**
- ✓ **Contribution to Climate Change**
- ✓ **Policy Development for Emission Control**
- ✓ **Alignment with International Climate Goals**
- ✓ **Lack of Previous Comprehensive Analyses**

02 Methodological Approach

Data Collection & Inventory Development

- Activity Data
- Emission Factors
- Geographic Disaggregation

GAINS Modeling Framework

- Bottom-up Approach
- Formula for Estimating Emissions

$$E_i = \sum_j \sum_k A_{i,j} \cdot ef_{i,j,k} \cdot X_{i,j,k}$$

- E_i = annual BC emissions for a country/region i,
- $A_{i,j}$ = activity level of type j in the region,
- $ef_{i,j,k}$ = BC emission factor for activity j and control measure k,
- $X_{i,j,k}$ = the share of activity j to which control measure k is applied.

Scenario Analysis

- Reference Emission Scenario (RES)
- Accelerated Reduction Scenario (ARS)

Sectoral & Sub-sectoral Analysis

- 7 Major Sectors & 15 Sub-Sectors

✓ **Residential combustion** (urban vs. rural, fuel types),

✓ **Transport** (diesel vs. gasoline, vehicle types),

✓ **Industrial processes** (e.g., brick kilns),

✓ **Waste burning** (municipal solid waste),

✓ **Agriculture** (crop residue burning),

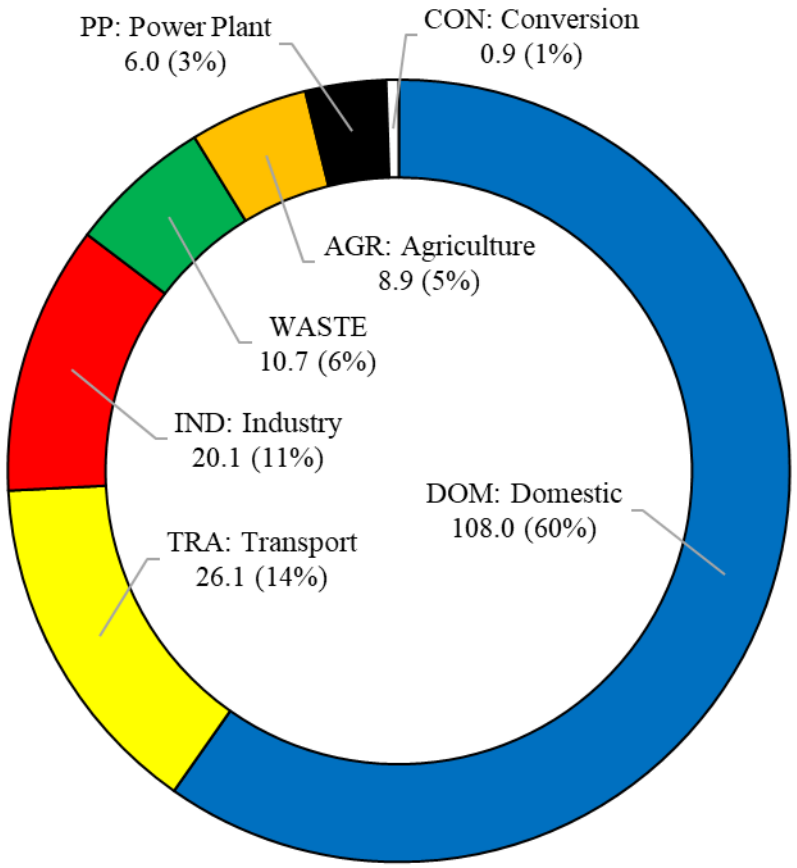
✓ **Power plants** (thermal power generation),

✓ **Fuel conversion** (oil and gas refining and flaring)

03 · Results

1. 2021 BC Emissions Inventory

Total BC Emissions in Pakistan for the Base Year 2021: 180.8 kt

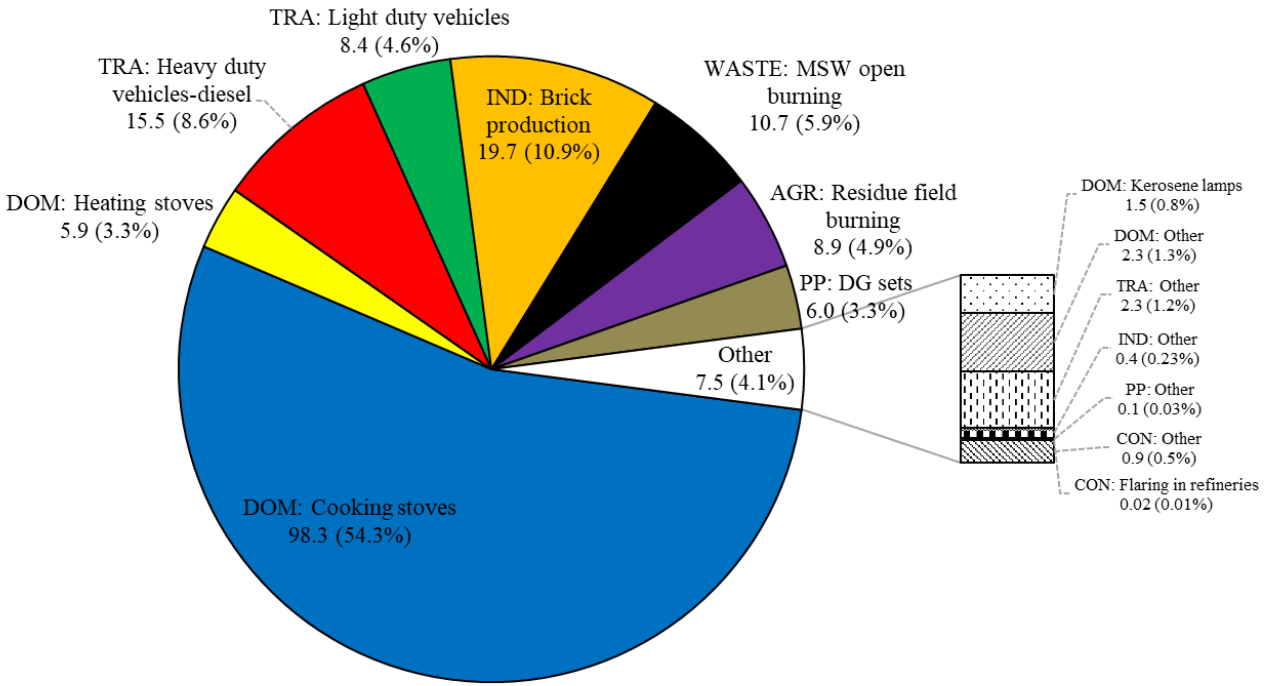


Major contributors to BC emissions in 2021 were:

- **Residential combustion**: **108 kt** (58.5% of total emissions), primarily from fuelwood used in cooking and heating stoves.
- **Transport sector**: **26.1 kt** (14.4%), with the majority coming from diesel-fueled heavy-duty vehicles.
- **Industry sector**: **20.1 kt** (11%), where **brick production** was the dominant source, accounting for 98% of the industry sector's emissions.
- Other significant contributors included:
  - **Municipal Solid Waste (MSW) open burning**: **10.7 kt** (5.9%),
  - **Agricultural waste burning**: **8.9 kt** (4.9%),
  - **Power plants**: **6 kt** (3.3%), primarily from diesel generator sets.

03 · Results

2. Sectoral Emissions Breakdown

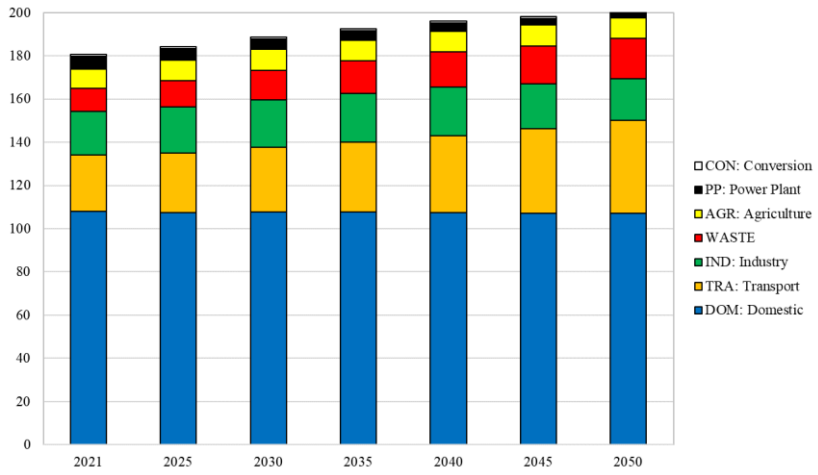


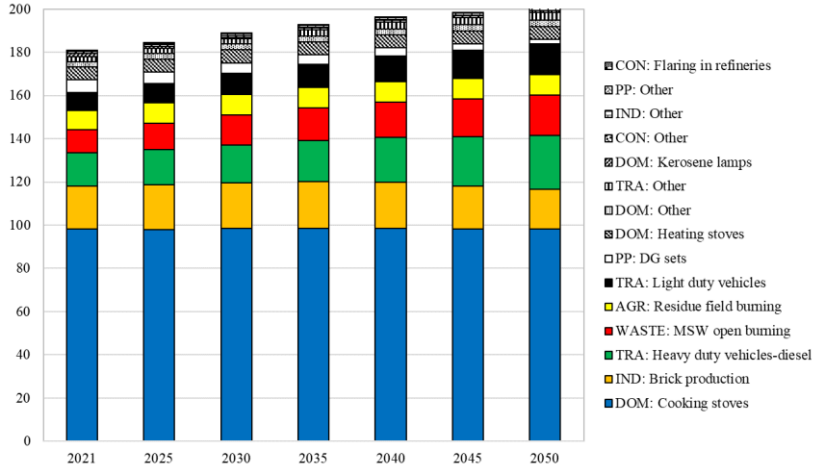
- **Residential**: Cooking stoves the largest source (98.3 kt), primarily from rural biomass use (fuelwood)
- **Transport**: Mostly from heavy-duty diesel vehicles, (15.5 kt – 96.8% of transport emissions)
- **Industry**: With brick kilns as the dominant source (19.7 kt)
- **Waste**: 10.7 kt from open burning of uncollected MSW.
- **Agriculture**: 8.9 kt from crop residue burning (wheat, rice, sugarcane)
- **Power Plants**: 6 kt from diesel generators; minimal coal emissions due to particulate controls

03 · Results

3. Scenario Projections

Reference Emission Scenario (RES)



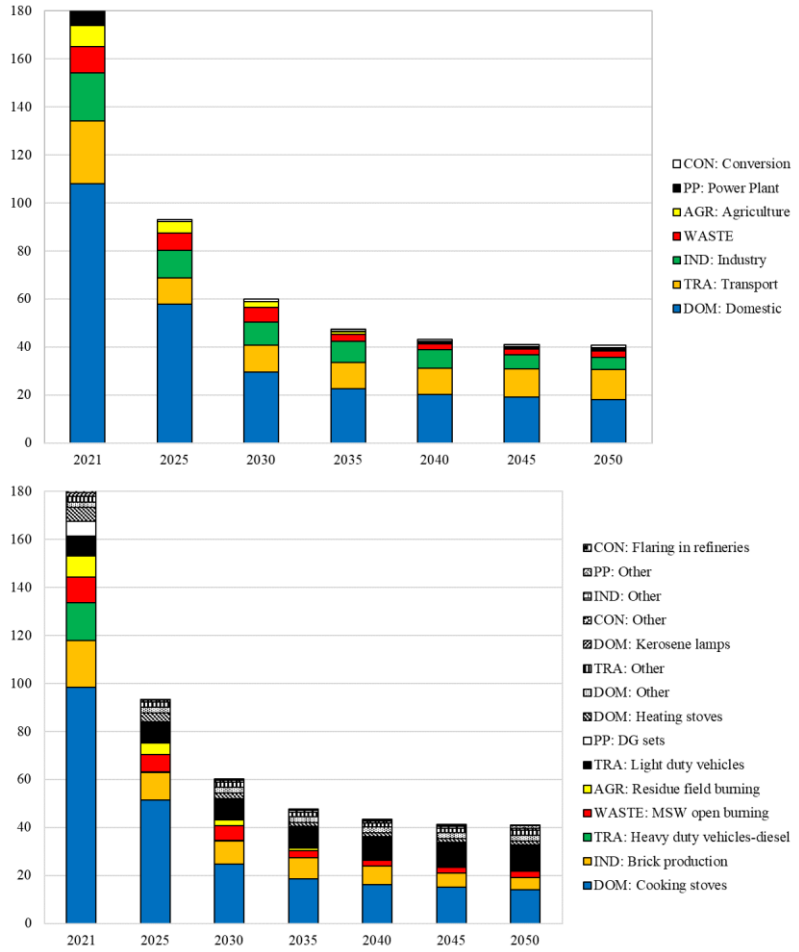


- Under the RES (continuation of current policies), BC emissions in Pakistan are projected to **increase to 200.9 kt** by **2050**
- The increase will be driven primarily by emissions from the transport, waste, and agriculture sectors
- Key sectoral projections by 2050 under RES:
  - **Domestic sector**: 107.3 kt (similar to 2021 levels)
  - **Transport sector**: 42.8 kt (63.9% increase)
  - **Industry sector**: 19.3 kt (slight decrease by 4%)
  - **Waste sector**: 18.7 kt (74.2% increase)

03 · Results

3. Scenario Projections

Accelerated Reduction Scenario (ARS)



- Under the ARS (aggressive mitigation strategies), BC emissions are projected to **decrease to 40.6 kt** by **2050** (a 78% reduction compared to 2021)

- Key reductions under ARS include:
  - **Domestic sector**: reduced to 18.2 kt (83% reduction),
  - **Transport sector**: reduced to 12.5 kt (52% reduction),
  - **Industry sector**: reduced to 5.0 kt (75% reduction),
  - **Waste sector**: reduced to 2.6 kt (76% reduction),
  - **Agricultural waste burning**: reduced to 0.5 kt (95% reduction).

04 · Key Conclusions

- **Residential combustion** is the largest source of BC emissions, followed by **transport, industry,** and **waste**
- Without additional measures, BC emissions will rise to **201 kt by 2050** (RES)
- With aggressive mitigation (ARS), emissions can be reduced to **41 kt by 2050**
- Key mitigation strategies include:

    i. Fuel switching (e.g., natural gas, electricity)
    ii. Improved cookstoves
    iii. Advanced emission controls
    iv. Bans on open burning of waste and crop residues

- Reducing BC will improve **air quality**, **public health**, and contribute to **climate mitigation**
- **Policy interventions** are essential in residential, transport, and waste sectors to achieve long-term emission reductions

05 Limitations

- **Data Quality:** Limited precision in sectors like residential combustion, brick kilns, and waste burning due to lack of detailed local data.
- **Emission Factors Uncertainty:** Generalized emission factors from literature; country-specific data is limited.
- **Lack of Field Measurements:** The study relies on modeled data, without direct measurements of BC emissions in Pakistan.
- **Real-World Effectiveness:** Assumed performance of mitigation technologies may not reflect real-world conditions.
- **Policy Enforcement Uncertainty:** The success of the ARS depends on strong policy implementation, which may face practical challenges.

05 Future Work

- **Develop Local Emission Factors:** Focus on creating more accurate, country-specific emission factors.
- **Field Measurements:** Conduct ground-based monitoring to improve BC emission data accuracy.
- **Assess Real-World Technology Performance:** Evaluate effectiveness of emission controls in real-world scenarios.
- **Address Socio-Economic Barriers:** Investigate challenges to adopting cleaner technologies (e.g., cost, infrastructure).
- **Explore Climate Co-Benefits:** Include health and climate resilience impacts to strengthen policy recommendations.

Acknowledgements

Thank you!

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